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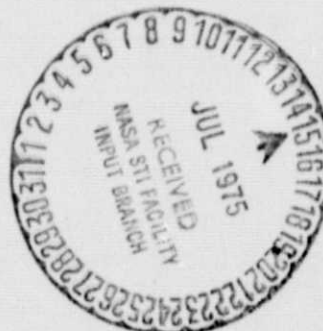
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**SUMMARY OF NASA-LEWIS RESEARCH CENTER SOLAR HEATING  
AND COOLING AND WIND ENERGY PROGRAMS**

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SUMMARY OF NASA-LEWIS RESEARCH CENTER SOLAR HEATING  
AND COOLING AND WIND ENERGY PROGRAMS

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SUMMARY

NASA is planning to construct and operate a solar heating and cooling system in conjunction with a new office building being constructed at Langley Research Center. The technology support for this project will be provided by a solar energy program underway at NASA's Lewis Research Center. The solar program at Lewis includes: testing of solar collector collectors with a solar simulator, outdoor testing of collectors, property measurements of selective and non-selective coatings for solar collectors, and a solar model-systems test loop.

NASA-Lewis has been assisting the National Science Foundation and now the Energy Research and Development Administration in planning and executing a national wind energy program. The areas of the wind energy program that are being conducted by Lewis include: design and operation of a 100 kW experimental wind generator, industry-designed and user-operated wind generators in the range of 50 to 3000 kW, and supporting research and technology for large wind energy systems. An overview of these activities is provided.

INTRODUCTION

Increased energy needs in the United States and a growing awareness of the limited availability of certain forms of energy, particularly gas and oil have spurred a search for alternate sources of energy. A joint NSF/NASA Solar Energy Panel, Ref. 1, recommended development of solar energy systems to heat and cool buildings, and development of wind systems to generate electrical energy. Previous investigators have shown these approaches to be technically feasible but high costs and uncertain reliability have prevented wide spread use of solar and wind systems. At NASA's Lewis Research Center efforts are in progress to provide the technology for efficient, reliable, low cost solar heating/cooling and wind energy systems.

NASA is also constructing a new office building at Langley Research Center, Hampton, Va. that will be partially heated and cooled with solar energy. This solar project is a joint effort between the Langley and

Lewis Research Centers, and is described in reference 2. NASA-Lewis will provide the solar energy system technology base for this solar project at Langley. At Lewis, solar collectors are being evaluated, both indoors under simulated sun conditions and outdoors. An investigation of promising collector absorber coatings is in progress. Also a model systems facility was constructed to study experimentally the dynamics of solar heating and cooling systems, and to verify computer simulation programs.

In 1973 the National Science Foundation (NSF) was assigned the responsibility for a national wind energy program. NSF and NASA agreed that under the overall program management of NSF, NASA-Lewis would provide project management for large experimental wind generator systems and for the development of supporting technology for these large wind systems, Ref. 3. In January 1975, the wind energy program was transferred from NSF to the newly formed Energy Research and Development Administration (ERDA), and NASA-Lewis is continuing to provide project management for ERDA.

This paper provides a summary of these activities, and lists references where more detailed information is available. These recent NASA-Lewis publications on solar and wind energy research may be obtained from the Technology Application Center, University of New Mexico, Albuquerque, New Mexico, 87106 for a nominal fee.

#### SOLAR HEATING AND COOLING PROGRAM

##### Langley Building Solar Project

NASA plans to utilize a new Systems Engineering Building (SEB) at its Langley Research Center as a test bed for solar heating and cooling systems investigations. The building is now under construction and occupancy is scheduled for early 1976. This solar energy project is a joint activity that involves both NASA-Langley and NASA-Lewis. The overall project responsibility is in the NASA headquarter's Office of Energy Programs.

The objective of this project is to determine the technical and operating characteristics of various kinds of solar collectors in a complete solar system being used to supply a significant part of the heating and cooling needs of an occupied building. This will enable us to find out how various components and subsystems work, and which ones work best. Ultimately, this and other similar kinds of information will be used to move toward solar heating and cooling systems that are economically competitive, have long life, and are reliable.

The SEB is to be a single-story office building having 53,000 square feet of floor area, and will provide office space for about 350 people. A photograph of an architect's model is presented in Figure 1. It will be located where typical mid-eastern seaboard weather conditions prevail. For air conditioning, the building will utilize a commercial 150 ton lithium bromide water chiller that is driven by hot water. Hot water will also be the energy source used for space heating. The building heating and cooling system will receive its hot water either from the solar system,



or from a steam-water converter driven from the Langley central steam supply system. Thus, whenever the solar system can supply all or part of the energy demand of the building, it will be used. Whenever auxiliary energy is needed, it will be supplied by the central steam system.

The solar energy research program at NASA-Lewis will provide the technology base for this NASA project.

#### NASA-Lewis Solar Technology

A solar technology program currently underway will provide the research and technology base to support the Langley Building solar project. The various outputs of the program will also contribute to advancing the general status of solar heating and cooling technology, as will the Langley Building project itself.

The Lewis solar technology program consists of efforts in four major areas:

- (1) Collector testing with a solar simulator
- (2) Collector testing on outdoor test stands
- (3) Coatings and materials studies
- (4) Operation of a solar-model-systems test rig

A highlight summary of these projects will be presented in this paper. More detailed information on this work is available in previous reports (Refs. 2, 4-9).

The Solar Simulator - The solar simulator was constructed so that solar collectors could be tested under controlled conditions. A photograph of the simulator is shown in Figure 2.

The simulator delivers artificial "sunshine" (air-mass 2 spectral distribution) uniformly over a 4-foot by 4-foot area. Generally, a test series consists of measuring collector efficiency at 3 or 4 flux levels (between 150 and 350 Btu/ft<sup>2</sup>/hr), for a number of inlet coolant temperatures (ranging from 100° F up to 210° F) and at a fixed water flow rate of approximately 10 lb/hr/ft<sup>2</sup> of collector surface. This flow rate is typical of that encountered in usual applications. In this range, collector efficiency is essentially independent of coolant flow rate.

The curves in Figure 3 indicate the results that we have obtained in the simulator to date. These two curves approximately bracket the operating curves we have obtained for over twenty collector configurations, although the slopes of all collectors are not the same as those shown in Figure 3. The upper curve was obtained from an advanced, experimental collector constructed with an aluminum absorber plate (coated with a flat, black paint), a plastic honeycomb, and covered with a single sheet of glass. The lower curve is from tests of a commercial hot water collector

(a Beasely Corp. "Solapak" unit) that used a copper tube sheet, a copper-oxide coating, and 2 glass covers.

The performance data shown in Figure 3 were obtained from Ref. 6. We define the collector efficiency as the ratio of energy absorbed by fluid flowing through the collector to the radiant energy incident upon the collector plane. The efficiency is plotted as a function of the temperature difference, from the fluid at the collector inlet to ambient air temperature, divided by the solar (simulated) flux. Thus, for a given flux value, as you move to the right on the abscissa, the temperature difference between the collector and its surroundings increases, resulting in increased heat losses from the collector. Consequently the collector efficiency is reduced. This format is particularly useful when employing the collector design parameters proposed by Hottel, Whillier, and Bliss in Refs. 10 and 11. All data in Figure 3 were obtained for direct radiation, normal to the solar collector. Using this experimental data, outdoor performance can be readily estimated for conventional flat-plate collectors. For designs incorporating features such as honeycomb structures, additional information about the effect of incident angle is required.

We plan to test in this facility all high performance collectors that appear to be of reasonably valid design. This includes collectors that we design and build, collectors we buy, and collectors whose ownership remains with the original owner. To provide cost-free test of a collector in this facility requires only that the owner give NASA the right to publish the data collected. Twenty-one collector configurations have been tested with the simulator as of March 1, 1975.

Some of the solar collector configurations that we have tested were developed by Honeywell, Inc., under a Lewis contract (NAS3-17862). The best performance of these configurations was obtained with a collector utilizing a roll-bond aluminum absorber plate coated with a black-nickel coating, backed by 3 inches of insulation, and covered by two panes of tempered glass that were treated with an anti-reflective coating. Not shown in Figure 3, this particular collector produced efficiencies higher at all values of  $\Delta T/q$  than any collector shown in Figure 3.

This collector produced an outlet water temperature of 230° F at a thermal efficiency of 58 percent, at an incident thermal flux of 300 Btu per hour per square foot of absorber surface. These conditions correspond to a  $\Delta T/q$  value of 0.48, as used in Figure 3. So far as we know, this represents the highest efficiency reported so far for a flat plate solar collector.

The Outdoor Collector Test Stand: - Collectors are also tested outdoors to determine the performance for the collectors operating under conditions encountered in operating solar systems. The outdoor facility permits evaluation of initial durability for a period of several months. Of course, the long-term durability will be established on the solar project at Langley. The data from the outdoor facility is being compared with the

data obtained from the simulator facility. To date, it appears that the outdoor behavior of some collectors, but not all, parallels rather closely the behavior displayed in the simulator, though with somewhat more scatter. We are still working on explanations for the cases where significant differences occur.

The outdoor collector test facility is shown in Figure 4. There is a second, identical, test stand providing a total capability to operate ten collectors independently and simultaneously. Collectors measuring up to four feet by eight feet can be readily accommodated, and larger collectors can be tested with minor changes to the facility.

A normal test consists of operating the collector at a constant inlet temperature and constant flow rate, and measuring the energy absorbed by the coolant flowing through the collector. This test is then repeated for different inlet temperatures. One set of collector data for a day are presented in Table I for a collector fabricated at the Lewis Research Center from two copper heat-transfer panels (Thermon Manufacturing Co.). The energy incident upon the plane of the collector is presented along with the energy absorbed by the coolant on an hourly basis. Between the hours of 9 AM and 4 PM the collector absorbed 41 percent of the energy available. Eight collectors have been tested outdoors as of March 1, 1975.

Coatings and Materials Studies - The coating and materials work is aimed primarily at determining what combinations of collector plate materials (such as steel, aluminum, and copper) and coatings yield the best collector in terms of initial performance, life, and low cost. In general, we are trying to identify as many coating candidates as possible and determine their properties (primarily absorptance and emittance). Then collector panels having the promising coatings are prepared for test in the simulator facility.

Figure 5 summarizes some of the measurements made to date. Absorptance,  $\alpha$ , is the property that determines how much of the energy in the solar spectrum (0.2 to 2 microns) is absorbed by the collector. Emittance,  $\epsilon$ , is the property that determines how much energy is lost by radiation from the collector. A body radiating at 200° F radiates maximum energy at a wavelength of 8 microns. The ideal dashed line in Figure 5 shows the desired characteristics, i.e., high absorptance, say 0.9 or greater, at the shorter wavelengths and low emittance on the order of 0.1, at the longer wavelengths. We have measured the optical properties of a number of coatings, including ordinary paint, enamels, anodized coatings, and solar selective coatings.

Measured values are shown for ordinary flat black paint, two commonly utilized "selective" coatings (CuO and black-nickel), and a relatively new solar selective coating, black-chrome (BL-CR), that came out of our recent studies. Ordinary black paint has a very high absorptance (which is good), but it also has a high emittance (which is bad). Our primary interest in black-chrome is that it provides an attractive alternative to black-nickel, and may cost less to apply, be more reliable (longer life), and perhaps be more appropriate chemically with some plate materials than



black-nickel. We are investigating these and other coating candidate materials so that comparative evaluations can be made.

Model-Systems-Test Rig - A solar model-systems-test facility has been constructed, and recently became operational.

The purpose of the model systems tests is:

- (1) To simulate the control and heat-storage dynamics of a solar heating and cooling system
- (2) To determine the ratio of the total heating and cooling demand of a building that can be supplied by solar energy
- (3) To provide an experimental verification for computer heating and cooling simulation programs.

Functionally, the system provides for solar heat input, auxiliary heating, heat storage, and heat delivery as shown in Figure 6. Heat input is provided by a steam-water heat exchanger when heat simulation is required or a solar collector field when the actual component is needed. Auxiliary heating is also provided by a steam-water heat exchanger. A cylindrical water tank is used for heat storage. Cold water flowing through a heat exchanger serves as the heat sink simulating the heat demand required from the solar loop. If heat energy is to be used for cooling, a subsystem is used. This subsystem consists of a water-chiller, a chilled water storage tank, and a heater to simulate the heat load of a building. Figure 7 is a photograph of the major components of the system.

The components have been sized according to the first application of the model-system facility -- the Langley solar building. The heating, cooling, and flow rates, are 1/50th of the Langley values, and the components have been sized accordingly. The thermal storage tanks, therefore, have a 600 gallon capacity for the hot water system, and a 400 gallon capacity for the chilled water. The water chiller is a lithium bromide absorption unit rated at 3 tons of refrigeration.

An essential feature of the system is the provision for programming the solar heat input to and the heating demand from the system. This is accomplished by translating the heating rates into a curve scribed onto a rotating drum. The curve functions as a cam, and the "cam" follower in turn controls the heat or cold load to and from the system. If insolation data is available at a location where a building design is contemplated, the model system can simulate the dynamics on a realistic operating basis.

The system is designed for a flexible arrangement of its component parts. When completed, it will have the capability to operate with either solar heat or auxiliary heat supplying the total load, or with the auxiliary heat topping the solar heat; heat input to the system can be a programmed simulation of solar heat, or it can be the heat that is absorbed by actual solar collectors; heating and cooling energy consumption can be programmed as a single energy demand, or the cooling subsystem can be



operated separately from the building heating requirements.

Recently a test was conducted where the available solar energy and building loads were determined using weather conditions recorded at Hampton, Virginia, for Aug. 3-6, 1959. The weather data was used in conjunction with NASA's Energy-Cost Analysis Computer Program (NECAP) to calculate the load for the office building at Langley. The experimental test results are presently being analyzed. Initial results of tests conducted to study temperature stratification in the hot water storage tank were presented in Ref. 2.

#### WIND ENERGY PROGRAM

In 1973, responsibility for the national wind-energy program was assigned to the National Science Foundation as part of the RANN (Research Applied to National Needs) program. Agreement was reached between NSF and NASA that, under the overall program management of the NSF, NASA-Lewis would provide project management for the large experimental wind generators and for the development of the supporting technology for these large wind systems.

In the fall of 1973 a major energy study entitled "The Nation's Energy Future" that was requested by the President was completed under the direction of the Chairman of the Atomic Energy Commission. This report recommended that approximately \$30 million be spent over the next five years on research to expedite the development of technology needed to build reliable and cost-effective wind-generator systems.

In January 1975, the wind energy program was transferred from NSF to the newly formed Energy Research and Development Administration (ERDA) and NASA-Lewis is managing a portion of the national 5 year program for ERDA. The NASA-Lewis wind-energy project includes three major elements: (1) design and operation of a 100 kW experimental wind generator, (2) industry-designed and user-operated wind generators in the range of 50 to 3000 kW, and (3) supporting research and technology for large wind-energy systems. This report summarizes the major elements. A detailed description of the program is presented in Ref. 3.

#### 100 kW Experimental Wind Turbine Generator

The objective of the experimental wind turbine generator is to provide, as soon as possible, engineering data for use as a base for the entire wind-energy program and to serve as a test bed for components and subsystems. To meet this objective, Lewis has designed and is constructing a wind-turbine generator large enough to assess the technology requirements and engineering problems of large wind-turbine generators yet small enough that construction and development costs do not exceed available budgets. In-house personnel have been used to apply current technology to initiate, immediately, a design for early construction and testing. This wind generator will also support research and technology by acting as a test-bed for various design concepts of blades, hub, pitch change mechan-

ism, system controls, and generators.

To meet these requirements a 100 kW machine has been selected as the candidate size. This machine will be mounted on a tower 30 meters (100 ft) high and contain two large blades each 62 feet (18.3 m) long, which are capable of pitch change and full feather. The program from design to construction is to be 18 months in duration with operation to start July 1975. Performance testing will then be conducted over a 12-month period. This test program will both evaluate the performance of the machine and make design improvements. The performance evaluation of the machine will emphasize the following:

- (1) To collect engineering performance data for use as a base for program direction and design of other follow-on wind-turbine generators of all sizes. This data will include energy and power output at various wind speeds; performance data on control systems; and loads, stresses, and vibrations on components such as blades, hub, and tower.

- (2) To identify the components and subsystems whose costs and maintenance need to be reduced; to acquire a basis for making realistic cost estimates.

- (3) To acquire data and experience on erecting and servicing, and attended and unattended operation.

- (4) To provide a test bed for field testing new and improved components and subsystems for support research and technology of windmills of all sizes.

- (5) To evolve design concepts for alternate applications.

The design of the 100 kW machine will utilize state-of-the-art technology where possible. Technology from other programs such as large helicopters will be applied particularly in the rotor design. Off-the-shelf components will be used where possible.

### System Description

The 100 kW experimental WTG (wind turbine generator) consists of a rotor turbine driving a transmission train and generator all of which are mounted on top of a tower, Figure 8. The rotor blades are located downwind of the tower. This arrangement provides maximum safety from blades' striking the tower and is also a more stabilized arrangement with respect to wind direction. Also in this arrangement the tower is subject to less dynamic interference, but the rotor blades see the effect of tower shadow.

Figure 9 shows a sketch of the yaw control and bed-plate with all the components mounted on it. Those components are enclosed in a fiberglass cylinder for protection from the environment. Reference 12 describes the design of the 100 kW machine.

The 100 kW experimental WTG is well underway. All systems have been

designed and all major items are being procured. The major components such as the hub, gearbox, generator, and shafts, etc. will be assembled and checked out in early spring prior to final assembly of the WTG at the site. Operation of the WTG is scheduled to begin in the summer of 1975.

#### First Generation Industry-Built User-Operated Wind Turbine Generators

The objective of the industry-built user-operated element of the NASA wind energy project is to involve industry and users in the design of optimized WTG systems that are capable of supplying electrical power into existing power networks at costs competitive with conventional power sources. It is planned to develop the necessary technology for these WTG systems that is needed for minimum costs and extended life so that rapid commercial implementation of WTG systems will result.

Also during the course of this effort, attention will be paid to evaluating the public reaction and/or acceptance of WTG systems. To meet these objectives a multiphased project is planned which includes the following phases:

- (1) Design study contracts
- (2) Evaluation
- (3) Detail design and fabrication contracts
- (4) Site selections
- (5) Operation of WTG systems

Figure 10 summarizes these phases and the planned accomplishment for each phase. The design and fabrication phases are primarily industry involvement and the site selection and WTG operation are primarily user involvement.

#### Design Study Contracts

The first phase of the industry-built user-operated WTG systems is the design study contracts. Two parallel 9-month contracts were awarded in mid-November for the preliminary designs of WTG systems optimized for minimum cost. The scope of the contracts was limited to horizontal axis machines. The contracts consist of four major tasks plus the final reports. The first task is the conceptual design of WTG systems. Each contractor is to evolve three promising concepts of WTG systems in the size range of 50 to 250 kW and three concepts of WTG systems in the size range of 500 to 3000 kW. At the conclusion of task 1 a single concept will be selected from each size range for minimum cost optimization and refinement. At the conclusion of the studies the minimum cost designs and sizes will be selected for preliminary design. In parallel with these tasks a fourth task will be conducted to determine the necessary interface requirements for operating a WTG on a utility network. The inputs from this task will influence the other three tasks. Applications other than utility



operation may prove practical but at this early stage of the program it has been decided to concentrate on the utility applications. The NSF mission studies will most likely identify other applications for which WTG systems appear promising and these inputs will also be considered in selecting the first sites and applications.

The two parallel contracts of approximately \$500 K each were awarded in mid-November for the design studies. One contract was awarded to the General Electric Company with a major subcontract to Hamilton Standard for rotor analysis. The General Electric Company has also contracted for the consulting services of Dr. Hutter during the contract. Dr. Hutter is a world recognized authority on the design of WTG systems. The second contract was awarded to Kaman Aerospace Corporation which has a sub-contract to Mueller Engineering for towers and electrical equipment specifications. Kaman also has a working agreement with Northeast Utilities for assistance on defining the utility interface requirements for a WTG.

#### Evaluation Phase

At the conclusion of the design study contracts, a six-month evaluation phase will be conducted. First, the results of the design studies will be evaluated and a selection made (integration of designs if necessary) of preliminary designs for size(s) and number of WTG systems to be fabricated. User participation particularly from the utilities will be solicited to aid in this evaluation. After the preliminary designs are selected, contracts will be awarded for final design and fabrication following a competitive procurement cycle. The size(s) and number of WTG systems to be built will depend on the program funding available.

#### Detail Design and Fabrication Contracts

The contracts for detail design and fabrication are planned to begin in early 1976. The contracts are planned to be 18 months in duration with approximately 6 months for detail design and 12 months for fabrication. These first generation WTG systems must utilize or extend existing technology in order to meet the planned schedules.

#### Proposed Plan & Schedule for Site Selection & User Involvement

In parallel with the design and fabrication phases, a user involvement and site selection phase is planned for identifying and selecting the sites for the operation of first generation industry built WTG systems.

#### User/Industry Coordination Phase

Following the site selections, that are planned for the late summer of 1976, the selected user is being requested to assign a person to interface with NASA and the WTG contractor. This person will work closely with the contractor during the fabrication phase and will provide necessary detailed site and interface information. Following completion of the WTG the users are expected to provide personnel for a cooperative



effort during installation and checkout and to provide necessary personnel for 2 years of operation.

#### WTG Operation Phase

During the 2-year operation of the WTG the contractor will be kept on board for routine inspections, any major problems that may arise, and for reporting of results. After the 2 years of operation, a decision on major modifications, possible relocation of the WTG, etc. will be made by ERDA/NASA. NASA and the contractor will be responsible during the 2 years of operation to obtain, evaluate, and publish WTG data. It is planned to release quarterly reports the first year with a semiannual and final report the second year. The resulting reports will be distributed to all interested organizations.

#### Supporting Research and Technology Including Energy Storage

The objective of the Supporting Research and Technology (SR&T) project is to evolve the technology that is needed to reduce the capital and maintenance costs of wind turbine generator (WTG) systems, components, and subsystems and at the same time improve their performance, reliability, and service life. Included in the objective is the creation of new and promising concepts for both components and subsystems, as well as total systems, and the development of promising methods for energy storage so that WTG systems can supply energy dependably.

Investigations in this project are divided into the following three areas: (1) subsystem and component technology development, (2) experiments with small WTG systems, and (3) energy storage systems that are particularly applicable to WTG systems. The SR&T studies that are funded by ERDA directly will be monitored by Lewis and the results integrated into the overall project.

#### Component and Subsystem Technology Development

It is planned to investigate and evaluate those WTG subsystems and components which offer the most potential for reduced costs, increased reliability, improved performance, and lower maintenance. Except for the horizontal axis rotors, however, SR&T plans for the major WTG subsystems and components such as towers, power conversion, power transmission, and controls have not been definitely formulated at this time. The several parallel sources which are being utilized to identify those subsystems and components which should be further investigated are: (1) the 100 kW experimental WTG at Plum Brook, (2) the two parallel industry-designed WTG system studies currently being performed, and (3) ERDA-funded SR&T tasks. The information resulting from these three sources will be evaluated to determine plans and investigations for improving WTG subsystems and components.

It is planned to test promising WTG subsystems and components in bench tests. The facilities for some of these tests are already set up as a result of the bench tests and assembly required for the 100 kW experi-

mental WTG. Following the bench tests, the subsystems and components with definite promise will be assembled into the 100 kW experimental WTG for field testing. This WTG has been designed as a test-bed for the resulting SR&T improvements.

Field Tests of WTG Systems - There is some question as to whether the analytical models are adequate for predicting the performance of WTG systems in the field, and whether the tunnel test results are valid in projecting what the field performance will be. To answer these questions, some small commercial WTG systems and some promising designs that emerge from other SR&T studies will be instrumented and tested in the field as well as in a wind tunnel by Lewis. The field tests will be done at the NASA Plum Brook site on a 22.8 meter (75 ft) tall WTG tower that was installed in December 1974. The results of the field tests will be compared with the analytical and wind tunnel results. From this comparison will emerge an assessment of the validity of using both the mathematical models and the wind tunnel for predicting the field performance.

Figure 11 shows the 22.8 meter (75 ft) WTG tower at Plum Brook and the 4.1 kW WTG that is presently under test. The 4.1 kW WTG was purchased through the Pennwalt Corporation of Texas from Aerowatt of Paris, France and has a 9.1 meter (30 ft) diameter rotor and delivers 4.1 kW at 7.5 meters per second (17 mph). This WTG uses a fly-ball type governor and operates at a nominal 50 hertz. The 30-foot diameter rotor is of a two-bladed design and represents the largest WTG rotor commercially available in the world today.

#### Experiments with Small WTG Systems in Actual Applications

Both NASA and ERDA are interested in identifying applications that are suitable for using small WTG systems such as power for individual homes, remote radio and TV relay stations, and navigation aids. The objective of these experiments is to acquire performance data, experience, and costs for the WTG systems that are used in actual applications.

One application for such experiments that is presently underway is that of supplying electrical energy to a remote relay station in the southwest Arizona desert. NASA-Lewis and NASA-Johnson Space Center (JSC) are cooperating in this experiment which is one task of the program STARPACH which JSC has with the Department of Health, Education and Welfare (HEW). STARPACH stands for Space Technology Applied to Rural Papago Advanced Health Care, and has as its objective the improvement of health care delivery to the Papago Indians in southwest Arizona. Essentially the health care delivery system consists of a mobile hospital van from which diagnostic and medical advice is given by television and voice communication. A remote relay station is an essential link between mobile hospital van in the field and the central hospital. This station requires about 1.5 kW of power and about 8 kW-hours per day of energy.

JSC has already equipped the relay station with a propane gas-generator system to supply the power. However, fuel must be supplied to the site every 10 days. Eventually the site will operate unattended. To

achieve this goal, JSC has given serious consideration to the use of a small WTG system and requested that Lewis assist in the experiment. In FY '75 Lewis will supply the WTG and battery storage system and JSC will supply the installation, operation, maintenance service, and all performance and cost data. From this experiment will result a better understanding of the costs and performance capability of WTG systems to supply power to remote relay stations.

Other experiments on the use of WTG systems to supply power to actual applications will be identified by ERDA and NASA. As they arise, they will be evaluated and conducted if the experiments are of value to the wind energy program.

### **Energy Storage Systems**

The ERDA Mission Studies will identify the most attractive applications for WTG systems and the amount of energy storage required. In parallel with this effort it is planned to conduct investigations on energy storage methods as part of the NASA-Lewis wind energy project.

A study is already underway to identify which of the energy storage methods might be most suitable for use with a WTG system. Systems under study include:

- (1) Battery storage
- (2) Redox cells
- (3) Compressed air
- (4) Fly wheels
- (5) Hydrogen

A small prototype energy storage system will be selected soon for use with the 100 kW experimental WTG. It is probable that this first system will employ batteries.

### **CONCLUDING REMARKS**

The NASA is planning to construct and operate a solar test bed system in conjunction with a new 53,000 square foot, single-story office that is being built at its Langley Research Center. The technology support for this project will be provided by a solar energy program underway at NASA's Lewis Research Center.

The supporting solar energy technology program at NASA-Lewis includes:

- (1) A solar simulator to test solar collectors under controlled conditions.



(2) Two outdoor collector test stands capable of testing ten collectors at once.

(3) Property measurements of non-selective and selective solar coatings on various substrate materials.

(4) A complete laboratory-scale solar-model-system test loop.

The overall goal of all of this work is to learn how solar heating and cooling components and systems work, and to make technology advancements necessary to achieve cost-competitive, reliable, long-life systems.

In 1973 the National Science Foundation (NSF) was given the responsibility for planning and executing a sustained wind energy program. The objective of this program is to develop the technology needed to build reliable and cost-effective wind energy conversion systems that have the potential for early and rapid commercial implementation. In January of 1975 the wind energy program was transferred from NSF to the newly formed Energy Research and Development Administration (ERDA). The NASA-Lewis Research Center has been assisting the NSF and now ERDA in the planning and execution of this program. Those areas of the national wind energy program that are being conducted by the NASA-Lewis for ERDA include:

- (1) Design and operation of a 100 kW experimental wind generator
- (2) Industry-designed and user-operated wind generators in the range of 50 to 3000 kW
- (3) Supporting research and technology for large wind energy systems.

To date our work in solar heating and cooling technology, and in wind energy systems has produced the following:

- (1) A flat-plate solar collector that will produce 230° F water at a collector efficiency of 58 percent (at a solar flux of 300 Btu per hour per square foot of absorber surface)
- (2) A solar-selective coating, "black-chrome", that holds promise for high performance, long-life, early commercialization, and acceptable cost
- (3) Over 3000 hours test experience with solar collectors in outdoor weather conditions
- (4) Unattended, instrumented operation of a 4 kW commercial wind generator for 2000 hours
- (5) The design of a 100 kW (electric) wind generator test device that will yield early operational experience and provide a basis for achieving cost-competitive, reliable machines
- (6) Conceptual designs for megawatt-size wind generators to be operated on utility company grids in 1977.



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TABLE I. - HOURLY COLLECTOR PERFORMANCE FOR JANUARY 24, 1975

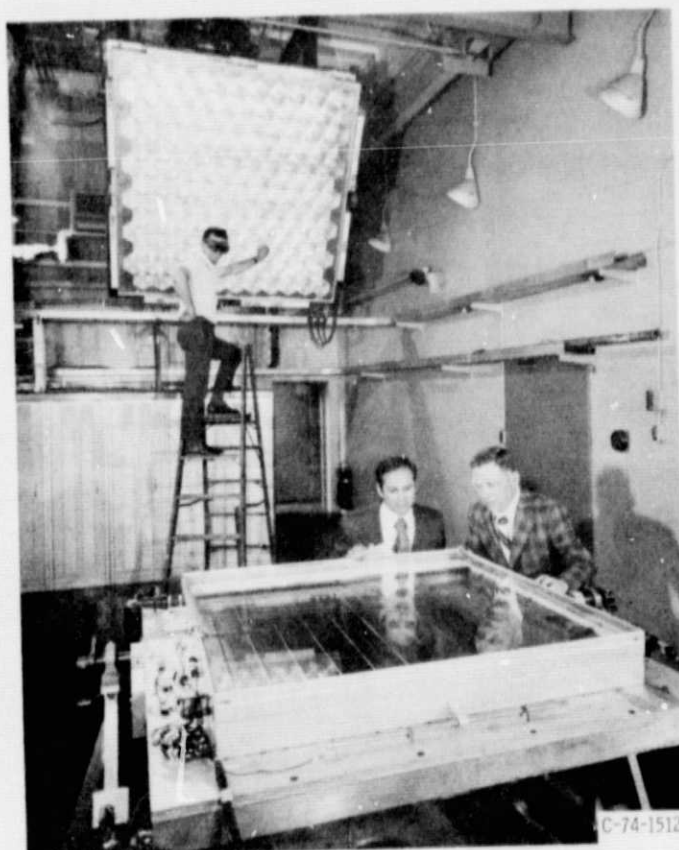
Hour (Solar Time)	Available Solar Energy (Btu/ft <sup>2</sup> )	Energy Collected (Btu/ft <sup>2</sup> )	Collector Efficiency (Percent)
9-10 AM	223	72	32
10-11 AM	274	115	42
11-12 AM	293	131	45
12-1 PM	287	147	51
1-2 PM	246	121	49
2-3 PM	212	73	34
3-4 PM	<u>136</u>	<u>29</u>	<u>21</u>
Tctal	1671	688	41

$T_{in} \sim 110^{\circ} \text{ F}$ ;  $T_{amb} \sim 48^{\circ} \text{ F}$ ; Wind  $\sim 7 \text{ mph}$



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Figure 1. - Architects model of solar building.



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Figure 2. - NASA-Lewis solar simulator facility.

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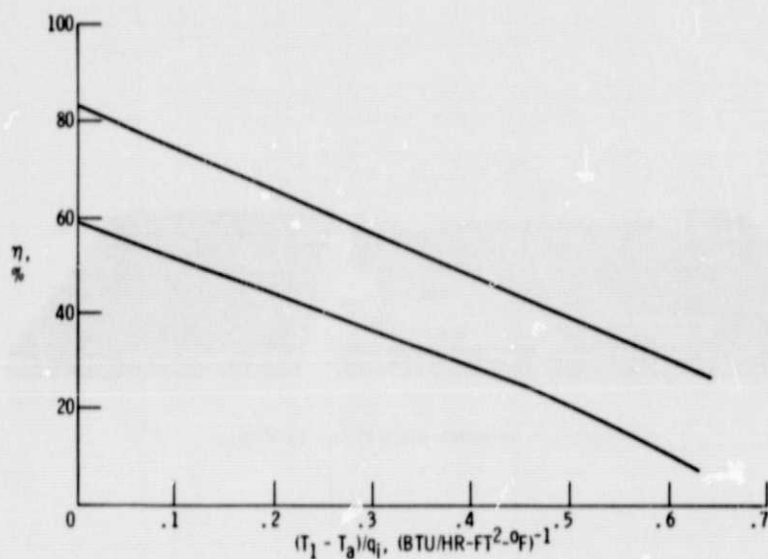


Figure 3. - Results of collector performance tests with NASA-Lewis solar simulator.



Figure 4. - NASA-Lewis outdoor collector facility.

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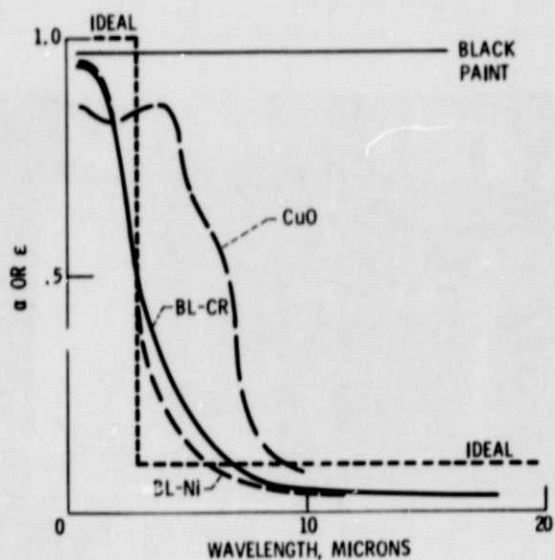


Figure 5. - Properties of solar coatings.

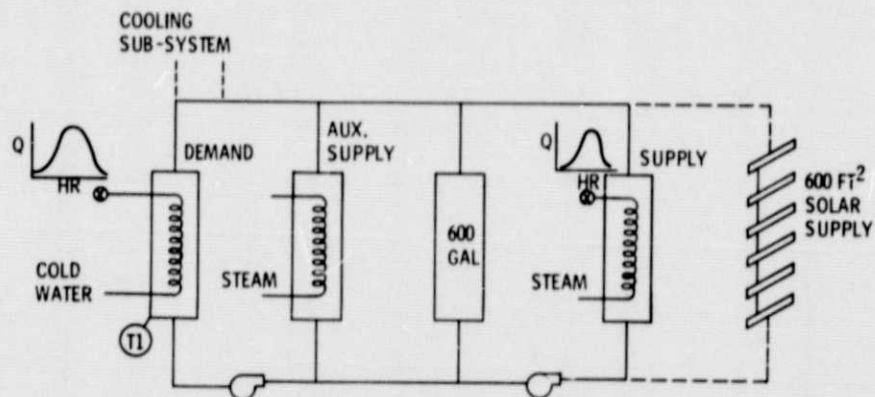


Figure 6. - Solar-model-systems facility schematic.

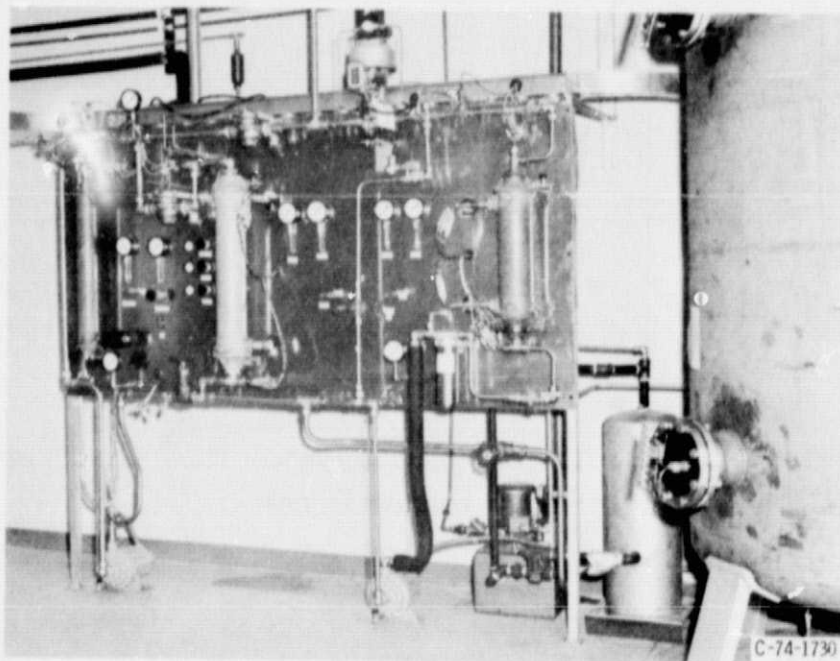


Figure 7. - Solar model systems facility.

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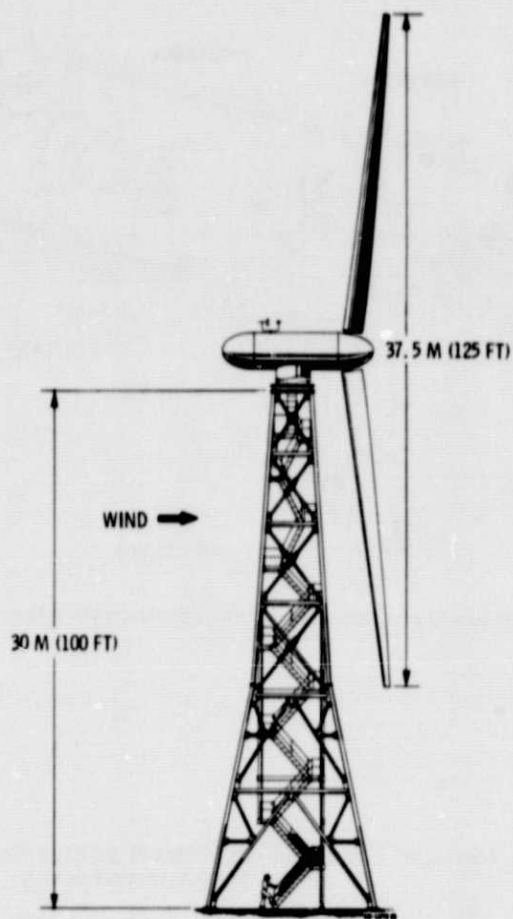


Figure 8 - 100-kilowatt experimental wind turbine generator.

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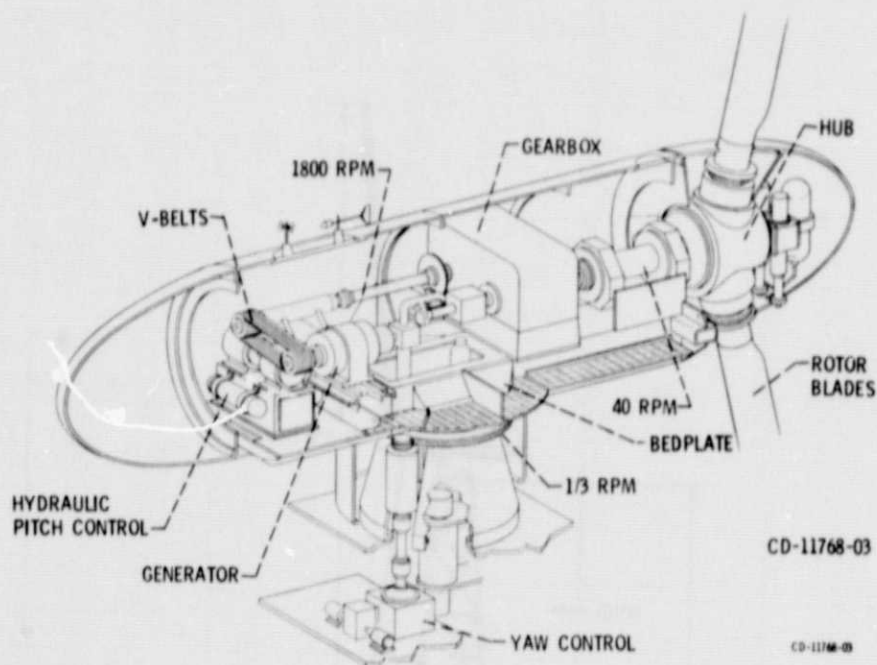


Figure 9. - 100-kilowatt wind turbine drive train assembly and yaw system.

DESIGN STUDY CONTRACTS	DETERMINE COST OPTIMUM (MINIMUM \$/KW-HR) WTO SYSTEM, PRELIMINARY DESIGN
EVALUATION	SELECT FINAL DESIGN(S) OF A WTG UNIT
DETAIL DESIGN & FABRICATION CONTRACT	DETAIL DESIGN & FABRICATION OF SEVERAL WTG UNITS
SITE SELECTION	NO. OF REPRESENTATIVE SITES
WTG OPERATION	EVALUATION OF THE PERFORMANCE OF WTG UNITS IN TYPICAL USER ENVIRONMENTS

Figure 10. - Project phases and accomplishments for industry-built WTG system.



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Figure 11. - 4.1 kW in operation at NASA.

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NASA-Lewis